

Technical Papers by IBM Authors Published Recently in Other Journals

Attenuation of High Energy Transverse Phonons, P. C. Kwok and P. B. Miller, *Physical Review* **146**, No. 2, 592-597 (June 10, 1966).

The role of four-phonon processes in the decay of high energy phonons, i.e., $\hbar\omega \gg k_B T$, from the lowest (transverse) phonon branch is discussed. The effects of the quartic anharmonic interaction, as well as the cubic anharmonic interaction calculated in the second Born approximation, are included. The largest four-phonon processes are found to be $t+t \rightarrow t+t$ and $t+l \rightarrow t+t$. A comparison of the four-phonon decay rate with the three-phonon decay calculated by Orbach and Verdevoe shows that both processes are very small at low temperatures, whereas at intermediate temperatures the three- and four-phonon decay rates are comparable in magnitude, the four-phonon rate being proportional to $\omega^2 T^6$ in the high-frequency region, i.e. for $\hbar\omega \gg k_B T$. A discussion of the relation between the present high-energy attenuation results ($\hbar\omega \gg k_B T$) and previous results obtained for low energy ($\hbar\omega \ll k_B T$) is presented.

Bouncing-Ball Pulse Generator, J. B. Gunn, *Electronics Letters* **2**, No. 5, 172 (May, 1966).

A technique is described for the generation of 1.5kV 200 ps pulses in a 50 Ω system. The switching action is controlled by bouncing a hard steel ball between contacts.

Burst Measurements in the Frequency Domain, W. T. Cochran,* J. J. Downing,** D. L. Favin,* H. D. Helms,† R. A. Kaenel,* W. W. Lang and D. E. Nelson,†† *Proceedings of the IEEE* **54**, No. 6, 830-841 (June, 1966).

Methods for measuring the energy density spectrum of burst-like events have been categorized. Five methods that rely on measuring samples of the energy density spectrum are distinguished. A tutorial exposition of the principles underlying these methods is given. This is the second phase of program by the IEEE Subcommittee on Methods of Measurement of Noise of the G-AE Standards Committee aimed at developing a unified approach to burst measurements and is an adaptation of the Technical Report on Recommended Practices for Burst Measurements in the Frequency Domain, IEEE No. 265.

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Chemical Nickel-Iron Films, A. F. Schmeckenbecher, *Journal of the Electrochemical Society* **113**, No. 8, 778-782 (August, 1966).

Ferromagnetic films, useful for computer applications, have been deposited from a modified Brenner bath by chemical reduction using hypophosphite. The deposits contain about 25% iron, 1-0.5% phosphorus, small amounts of oxygen, carbon, etc. The balance is nickel. The films are well suited for memory applications because of their high creeping threshold and their fast coherent rotational switching. The effects of certain plating parameters on the properties, in particular on the magnetic properties, are discussed.

Combining Laminar Flow Work Stations with Closed Loop Cleaning, H. Heuring, *Contamination Control* **5**, No. 7, 10-13 (July, 1966).

Cleaning for two critical Saturn systems assembled by IBM requires practically zero-contamination conditions. This paper describes a method of combining laminar flow benches and other clean room equipment to provide maximum efficiency with a minimum amount of space. It covers the design of the equipment and facilities, the problem areas, and the results.

The hardware to be cleaned, the cleanliness levels, and the end product are discussed first. Methods, materials, and cleaning requirements are described. An explanation is given of the manufacturing engineering considerations involved in the decision to utilize laminar flow work stations, specially adapted to an original configuration. An ultra-clean environment was achieved within a lower-rated, less expensive room.

The Compatibility of Value Engineering and Configuration Management, M. Wasserman, *Proceedings of the Third Space Congress*, pp. 437-451 (March, 1966).

This paper is aimed at management people responsible for ensuring system compatibility and mission success. It discusses the philosophies of system management and the interrelationships of program management, system engineering, and management tools. Value Engineering and Configuration Management are discussed as the catalysts to be integrated into the management network, thus ensuring system compatibility and mission success at the lowest overall cost. The Aerospace Industries Association (AIA) has stated that Configuration Management and Value Engineering are not compatible. This paper is offered in rebuttal to that statement.

Compositional X-Ray Topography, J. K. Howard and R. D. Dobrott,* *Journal of the Electrochemical Society* **113**, No. 6, 567-573 (June, 1966).

The advent of new semiconductor materials frequently demands new methods of investigating and defining those growth flaws which can degrade device performance. A new x-ray topographic method and concept were developed to study the defect structures in the heteroepitaxial systems. Compositional x-ray topography is an extension of the scanning-reflection method, which permits a nondestructive evaluation of the perfection in the substrate, deposit, and heterojunction. The theory and limitations of this method are discussed. Compositional x-ray topography was applied to the study of homogeneity and perfection in various heteroepitaxial systems, i.e., GaAs-GaP, GaAs-InAs.

* Texas Instruments Incorporated, Dallas.

Computer Produces Precision Drawings, R. G. Beard and A. E. Singiel, *The Tool and Manufacturing Engineer* **56**, No. 6, 76-77 (June, 1966).

To relieve the demands on engineering time, manufacturing engineers have effectively "harnessed" a computer and a plotter to produce precision drawings. The example discussed is how computers are being used to draw comparator charts for parts inspection.

Computerized Tool Control, J. W. Justice and R. A. Gaio, *Production* **58**, No. 1, 75-78 (July, 1966).

A total tool control program, being implemented at IBM Rochester, that controls the physical inventory, maintains tool drawings, generates tool geometry, and provides rapid-access where-used and cost records for approximately 5000 perishable tools is discussed. The control system accomplishes these functions through use of punched cards, computers, and data phone terminals.

Direct Correlation Between Domain Size and Coercive Force in Iron Alloys, J. A. Pesch, *Journal of Applied Physics* **37**, No. 7, 2627-2630 (June, 1966).

The Bitter technique was used to observe magnetic domain patterns on specimens of polycrystalline iron and iron containing 2.5 wt% silicon. Domain patterns that appear on grains oriented close to (110) [001] with respect to the specimen surface were observed. A critical domain size indicator S , based on measurements of domain size with the specimen in the demagnetized state, was developed and found to vary inversely with the coercive force. Values of S ranging from 0.23×10^{-3} cm were measured on iron specimens having coercive force values from 2.75 Oe down to 0.43 Oe. Similar results were obtained for the 2.5% Si-Fe alloy. Domain patterns were also observed under changing applied field conditions. In the region of the coercive force, "spike" domains annihilated one another and also joined together to form a continuous volume of reverse magnetization. The domain interactions suggest an unstable condition between domain wall energy and volume energy, followed by the interaction of domains which resulted in a lower wall energy.

Distribution of Boron-Induced Defects in Shallow Diffused-Surface Layer of Silicon,† H. Rupprecht and G. H. Schwuttke, *Journal of Applied Physics* **37**, No. 7, 2862-2866 (June, 1966).

Chemical sectioning of p -type surface layers on silicon is described. The technique is applied to measure the impurity concentration and the defect concentration vs depth in shallow boron-diffused surface layers using electrical measurements and x-ray diffraction microscopy.

† Sponsored in part under Contract AF 19(628)-5059.

Dynamical Behavior of Exchange-Coupled Spins, Paul Erdős, *Helvetica Physica Acta* **39**, No. 2, 155 (April 1, 1966).

The magnetic resonance conditions and dynamic susceptibilities of a two-spin system are derived. The spins are coupled through a combination of isotropic and asymmetric exchanges. This type of interaction occurs in weak ferromagnets. A method is developed which permits the summation of the perturbative series for the wave function in the case of resonance.

A Dynamic Determination of the Anisotropy Field and the Damping Constant of Thick Magnetic Films, H. H. Zappe, *IEEE Transactions on Magnetics* **MAG-2**, No. 2, 73-76 (June, 1966).

A new dynamic method for the measurement of H_k and the damping constant T of thick magnetic films is presented from both the theoretical and practical standpoint. The method is based on a property of the differential equation

$$TH_k \frac{d\theta}{dt} = H_y \cos \theta - H_x \sin \theta - H_k \sin \theta \cos \theta$$

which has been found to be adequate if applied to the read cycle.

It is found that, if the easy axis sense signals obtained with linearly rising hard axis fields of different rise times are plotted versus the respective hard axis fields, the maxima of the sense signals lie almost precisely on a straight line. This straight line cuts the field axis at H_k . From the slope of this line it is possible to deduce T which is primarily the eddy current time constant for thick films. The resistivity of the magnetic material can, in this case, be evaluated directly if the physical dimensions of the film are known. The influence of dispersion and skew is discussed, and found to be reasonably small. Further advantages are that no instrumental integration is needed, and that the reading is quite precise. Small variations of H_k can, therefore, be easily recorded. Practical results obtained with thick magnetic films illustrate this method.

Effect of Anisotropic Anharmonicity on Acoustic Attenuation, N. S. Shiren, *Physics Letters* **20**, No. 1, 10-12 (1966).

Previous theories of acoustic attenuation by three-phonon collinear processes have effectively assumed third-order elastic isotropy and predicted attenuations varying with frequency ω and temperature T as ωT^4 at low temperatures.

In this note it is shown that when the lattice anharmonicity is assumed anisotropic the resulting frequency and temperature dependences of attenuation strongly reflect the degree of anisotropy.

Effect of NH_3 on Deposition from Alkaline Electroless Nickel and Cobalt Plating Baths, G. S. Alberts, R. H. Wright, and C. C. Parker, *Journal of the Electrochemical Society* **113**, No. 7, 687-690 (July, 1966).

The ammonia generally used as a buffer in alkaline electroless nickel and cobalt plating baths has been shown to have a significant effect on both the rate of deposition of thin metal films and the magnetic and physical properties of such films. These effects have been studied on both metallic and nonmetallic substrates, using both ammonia and non-ammine buffer systems, and attempts have been made to correlate them with spectral and polarographic observations.

Effect of Oxygen Pressure on Electrical Conductivity in Silicate Glasses, R. C. Buchanan and W. D. Kingery,* *Proceedings of the Seventh International Congress on Glass*, Brussels, pp. 368.1-368.11 (July, 1965).

The extent to which silicate glasses show electronic conduction when melted in an oxygen atmosphere was investigated. Samples of sodium silicate, sodalime silicate and lead silicate glasses were melted in platinum crucibles under oxygen pressures of up to 100 atmospheres. Property measurements made included optical absorption, sodium ion transference number, oxygen concentration, cell emf, electrical conductivity, density and refractive index. Results indicating increase in the latter four properties compare to an air melted sample as well as the presence of an absorption peak at about 2250 Å. The conductivity increase was shown to be mostly electronic in nature and is believed due to the movement of holes associated with the ionization of dissolved oxygen.

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Electron Tunneling from Metal to InSb, L. L. Chang, L. Esaki and F. Jona, *Applied Physics Letters* **9**, No. 1, 21-23 (July 1, 1966).

We report in this Letter measurements of electron tunneling from a metal to heavily doped InSb through a thin oxide layer. The general characteristics of conductance vs applied voltage for both *n*- and *p*-type crystals were obtained and interpreted using a simple tunneling model. In addition, some structures in the characteristics are observed near zero bias and at an energy of 0.75 eV in the conduction band of InSb. The latter is believed to be due to the L_1 sub-band minimum.

Electron Tunneling Measurement of a Small Energy Gap in Lanthanum, A. S. Edelstein and A. M. Toxen, *Physical Review Letters* **17**, No. 4, 196-198 (July 25, 1966).

This Letter reports the first electron tunneling measurements of an energy gap in lanthanum. The measured value for $2\Delta_0/kT_c$ of 1.65 ± 0.15 is considerably lower than the value predicted by the Bardeen-Cooper-Schrieffer theory,

3.52. At voltages above that at which the gap is observed, an increase in conductance is also observed. This might be due to the *f*-band quasiparticle excitations predicted by the model of Kuper, Jensen and Hamilton.

Electronic Data Processing and the Personnel Function: the Present and the Future, C. E. J. Cassidy, *Personnel Journal* **45**, No. 6, 352-354 (June, 1966).

The results of an electronic data processing survey sent to personnel directors of various companies are reported. Specific present uses of data processing by personnel directors is reported and an estimate of future use is given.

Experience with FORMAC Algorithm Design, R. G. Tobey, *Communications of the ACM* **9**, No. 8, 589-597 (August, 1966).

Various facets of the design and implementation of mathematical expression manipulation algorithms are discussed. Concrete examples are provided by the FORMAC EXPAND and differentiation algorithms, a basic FORMAC utility routine, and an experiment in the extraction of the skeletal structure of an expression. One recurrent theme is the need to avoid excessive intermediate expression swell in order to minimize core storage requirements. Although many details from the FORMAC implementation are presented, an attempt is made to stress principles and ideas of general relevance in the design of algorithms for manipulating mathematical expressions.

Experimental Determination of the Density of States in Nickel,† A. J. Blodgett, Jr. and W. E. Spicer,* *Physical Review* **146**, No. 2, 390-402 (June 10, 1966).

Energy distributions of photoemitted electrons and spectral distribution of quantum yield from nickel in the range of photon energy 4.8 to 11.6 eV are presented and used in conjunction with the optical data of Ehrenreich, Philipp, and Olechna to deduce the electronic structure and optical selection rules of Ni. No evidence is found in these data consistent with the assumption that conservation of *k* is an important selection rule. Rather, it is found that first-order agreement is obtained between both the optical and the photoemission data if the optical transition probability is assumed to depend only on the initial and final densities of states. The density of states in the energy regions $-6.0 \leq (E - E_F) \leq 0$ and $5.0 \leq (E - E_F) \leq 11.6$ eV (E_F is the Fermi level) is determined directly from the photoemission data. The density of states in the region $0 \leq (E - E_F) \leq 5.0$ eV is determined using the photoemission results in conjunction with optical data. The most notable feature of the experimentally determined density of states is a strong maximum 4.6 eV below the Fermi level. Weaker maxima are found at 0.3 and 2.2 eV below E_F . A relatively high density of empty states is found in the conduction band within 0.5 eV of the Fermi level (empty *d*-like states), and the density of states is approximately constant in the region $0.5 \leq (E - E_F) \leq 11.6$ eV (low-density *s*- and *p*-like states). It is shown that the experimentally determined Ni density of states cannot be reproduced from that of Cu via the rigid-band model no matter what value of exchange splitting is chosen.

† Work supported by the National Science Foundation, and by the Advanced Research Projects Agency through the Center for Materials Research at Stanford University.

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Heat Sensitive Materials Joined by NC Welder, R. A. Goodrich, *Steel* **159**, No. 4, 29-30 (July 25, 1966).

A versatile and highly precise numerically controlled welder, designed and built to IBM specifications, is being used for production runs at IBM Rochester. The unit consists of a force-resistant automatic welder, a numerically controlled positioning table and a weld parameter control unit.

Heats of Solution of Some Tetraalkylammonium Salts in Water and in Propylene Carbonate and Ionic Enthalpies of Transfer from Water to Propylene Carbonate, Y. C. Wu and H. L. Friedman, *Journal of Physical Chemistry* **70**, No. 6, 2020-2024 (June, 1966).

In an extension of earlier work the enthalpies of transfer of several additional ions from water to propylene carbonate at 25° were determined calorimetrically. The results for ΔH° relative to that for Na^+ are: Me_4N^+ , -1.45; Et_4N^+ , 2.65; Cl^- , 3.83; Br^- , 0.85; I^- , -3.22 (all in kcal/mole). Apparently these conventional single-ion values and those reported earlier are quite close to the real, or absolute, single-ion enthalpies of transfer. Most of the results can be understood in terms of well-known structural effects in the water solutions, but this does not seem to be true of the enthalpy of transfer of $\text{B}(\text{C}_6\text{H}_5)_4^-$.

High Energy Emission in GaAs Electroluminescent Diodes, M. I. Nathan, T. N. Morgan, G. Burns and A. E. Michel, *Physical Review* **146**, No. 2, 570-574, (June 10, 1966).

A study of high-energy proton emission ($h\nu - eV \gg kT$) from various GaAs diodes is reported and the results analyzed. We find that this emission is produced by most diffused diodes except those doped with Sn and Ge. It is not observed in solution-grown diodes, no matter what the doping. It is always accompanied by a large amount of excess (nonradiative) current and can be explained in terms of the Auger recombination of carriers at defects with subsequent diffusion of the excited electrons to the p side of the junction.

High-Resolution Photolithography and Monolithic-Circuit Fabrication, P. P. Castrucci, R. H. Collins and W. R. Marzinsky, *Reprographics* **4**, No. 5, 10-15, 26, 35 (July, 1966).

This paper describes the photolithographic process and its role in the fabrication of monolithic integrated circuits. Included is a description of the materials, techniques, and overall fabrication process.

History, Features and Commentary on FORMAC, E. R. Bond, *Communications of the ACM* **9**, No. 8, 548 (August, 1966).

FORMAC, an extension of IBM 7090/94 FORTRAN, is an experimental programming system to assist in the symbolic manipulations of mathematical expressions. It is a system that performs tedious, but routine, algebra and analysis on a computer.

This paper attempts to convey an overall understanding of the significant features of the FORMAC system. Other reports that explore the system in depth are listed in the bibliography.

How to Disassemble Glass-Sealed Components, W. F. Traber and R. N. Wood, *Laboratory Management* **4**, No. 6, 26-27 (June, 1966).

Glass-sealed devices, such as electron tubes, light sources, and reed relays, contain intricate component parts. If it becomes necessary to perform an analysis on any of these parts, a means must be available to disassemble the structure without physically shocking the enclosed parts, rubbing them against other components, or against the sides of the glass envelope itself. If the part can be removed free of damage, then subsequent analyses have a much higher confidence factor. One means of accomplishing this sample preparation is as follows: Hold the sealed device with micromanipulators, and then slice the glass with a hot nichrom wire and liquid nitrogen. This procedure permits the components to be carefully withdrawn without introducing external contamination.

Impurity Segregation in Binary Compounds, M. R. Lorenz and S. E. Blum, *Journal of the Electrochemical Society* **113**, No. 6, 559-563 (June, 1966).

The effect of the pressure of the constituents of a binary compound on the segregation coefficient (k_o) of a substitutional impurity is considered. The theory concerning the incorporation of an impurity is briefly reviewed, and the dependence of k_o on P_M is given for various combinations of electrical character of an impurity and the site the impurity occupies. The impurities In and Sb were studied in CdTe. $k_o(\text{In})$ is inversely proportional to P_{cd} and $k_o(\text{Sb})$ is directly proportional to P_{cd} . The results are in quantitative agreement with the theoretical prediction if it is assumed that native defects play a negligible role as a source of free carriers or charge compensation.

The Information Profile, D. E. Olson, *STWP Review* **13**, No. 3, 6-8 (July, 1966).

This article describes development of the Information Profile. This is a newsletter-type publication that catalogs current information from various sources that are of interest to engineers. Regularly listed are professional meetings, news about the industry, trade press articles of interest, new books added to the library, new reports and papers published, calls for papers, new marketing publications, and new information added to the corporate information center.

Library Systems Analyst—A Job Description, T. Minder, *College and Research Libraries Journal* **27**, No. 4, 271-276 (July, 1966).

With the increased use of system analysis techniques in libraries, the time has come to consider the extent of systems analysis in librarianship and the duties of the analyst. This is a discussion of the job description, prerequisites and functions of a library's principal analyst.

Low-Drift Current Generator Compensates for Temperature, C. C. Hanson, *Electronics* 39, No. 12, 108-109 (June 13, 1966).

The temperature-compensated current generator described solves the problem of obtaining sufficient input base current in circuits where common-mode voltages are applied at the input terminals. The solution is based on the fact that matched transistor pairs—as used in differential amplifiers and precision voltage comparators—have base-current temperature coefficients which are predictable as a function of operating current.

Magnesium-Lithium Alloy Lightens Electronic Packaging, R. A. Munroe, *Metal Progress* 90, No. 1, 89-92 (July, 1966).

Saturn rockets have computer equipment with a framework of LA141A, a magnesium alloy with extra low density (0.049 lb per cu. in.) Because the alloy has a body-centered cubic structure with three slip planes, it is readily fabricated by conventional practices.

Magnetic Properties of Solid Solutions of the Heavy Rare Earths with Each Other, R. M. Bozorth and R. J. Gambino, *Physical Review* 147, No. 2, 487-494 (July 15, 1966).

The Curie and Néel points, and other critical points, of alloys of heavy rare earth elements with each other have been determined for 14 binary alloy systems. To a good approximation the Néel points of all of the alloys vary linearly with the $\frac{3}{2}$ power of the average de Gennes factor, $J(J+1)(g-1)^2$, as previously known. The Curie points, however, are definitely characteristic of the alloy system, each system showing a different dependence on concentration. The properties of each system are discussed, and related when possible to the transformations found in the elements and to atomic processes. Special effects are noted when the average 4 electron concentration lies between 10 (Ho) and 11 (Er), where the Stevens factor changes sign. Magnetization processes in several alloys are interpreted according to the model of Kitano and Nagamiya.

Magneto-Oscillatory Conductance in Silicon Surfaces, A. B. Fowler, F. F. Fang, W. E. Howard and P. J. Stiles, *Physical Review Letters* 16, No. 20, 901-903 (May 16, 1966).

We have observed Shubnikov-de Haas oscillations in a two-dimensional electron gas in the (100) surfaces of *p*-type silicon inverted by an electric field perpendicular to the surface.

Measurement of Third-order Elastic Moduli of Yttrium Iron Garnet, D. E. Eastman, *Journal of Applied Physics* 37, No. 6, 2312-2316 (May, 1966).

The third-order elastic moduli of yttrium iron garnet (YIG) have been determined from measurements of ultrasonic velocity. A pulsed ultrasonic system which uses a phase comparison principle to measure velocity versus applied stress is described.

Negative Field Effect Mobility on (100) Si Surfaces, F. F. Fang and W. E. Howard, *Physical Review Letters* 16, No. 18, 797-799 (May 2, 1966).

The surface mobility of carriers in an *n*-type inversion layer has been studied by field-effect experiments with metal-oxide-semiconductor structures. It was shown that at moderate fields the carriers suffer from surface scattering and the surface mobility, as measured from both field-effect mobility and the surface Hall effect, is reduced with increasing field.

Numerical Inversion of Laplace Transforms Using Laguerre Functions, W. T. Weeks, *Journal of the ACM* 13, No. 3, 419-429 (July, 1966).

A method is described for the numerical inversion of Laplace transforms, in which the inverse is obtained as an expansion in terms of orthonormal Laguerre functions. In order for this to be accomplished, the given Laplace transform is expanded in terms of the Laplace transforms of the orthonormal Laguerre functions. The latter expansion is then reduced to a cosine series whose approximate expansion coefficients are obtained by means of trigonometric interpolation. The computational steps have been arranged to facilitate automatic digital computation, and numerical illustrations have been given.

Observation of Photon Counting Distribution for Laser Light Below Threshold, A. W. Smith and J. A. Armstrong, *Physics Letters* 19, No. 8, 650-651 (January, 1966).

Using the light from a single axial mode of a He-Ne laser operating below but close to threshold we have observed the probability distribution for the number of photons, *n*, counted in a fixed time. This fixed time was shorter than the coherence time of the intensity noise in the light. The observed distribution corresponds closely to a geometric distribution; such a distribution is characteristic of an ensemble of Bose-Einstein particles (in this case photons) described by a density matrix which is diagonal in particle number states.

On the Measurement of the Complex Spatial Coherence of a He-Ne Laser Beam, J. V. Cornacchio and K. A. Farnham, *Il Nuovo Cimento* 42, No. 1, 1232-1244 (March, 1966).

The feasibility of determining by experiment the magnitude and phase of the complex spatial coherence of a laser beam using the recently derived inversion expression for complex spatial coherence is demonstrated. Both magnitude and phase dependence for two laser excitation levels for a wide range of correlation intervals is presented. The ratio of the degree of coherence at the two levels for a continuous range of correlation intervals is evaluated yielding results consistent with other known experimental facts. The degree of coherence was found to be lower at the higher level of laser excitation. The use of the inversion expression for the experimental determination of the complex spatial coherence for narrow linewidth beams is pointed out. The difficulty in presently establishing the spatial stationarity of the beam, and its relation to the applicability of the inversion expression are discussed.

The Potentials of Computer-Assisted Instruction in Industry, H. S. Long and H. A. Schwartz, *Training and Development Journal* **20**, No. 8, 6-17 (September, 1966).

As modern industry grows in both size and complexity, the problems of industrial education mount rapidly. Accomplishing the necessary training in a work-oriented environment, in widely dispersed locations, and with heterogeneous groups of both students and instructors has proven to be almost impossible with classroom methodology. Recent techniques, notably Programmed Instruction, have been of immeasurable value in dealing more effectively with the situation. These techniques, however, may involve problems in such areas as control of the student, data collection, and course preparation.

Teaching systems, consisting of centralized computers and remotely located student and author terminals appear to provide a means of combining the decentralized, self-pacing benefits of Programmed Instruction with the student control and student feedback features of the classroom. Feasibility studies of computer-assisted instruction in an operational environment are presently being conducted.

A Prediction of the Photoresist Influence on Integrated Circuit Yield, T. R. Lawson, Jr., *Semiconductor Products and Solid State Technology* **9**, No. 7, 22-25 (July, 1966).

A method, based largely on statistical and theoretical grounds, is given to relate maximum photoresist yield to the defect density of the resist. For the particular circuit analyzed, the yield is logarithmic and given by $\log(\text{yield}) = -0.4326(\text{density of defects})$.

Properties of Amorphous Silicon Nitride Films, S. M. Hu, *Journal of the Electrochemical Society* **113**, No. 7, 693-698 (July, 1966).

This paper describes insulating films of silicon nitride as deposited on silicon substrates by pyrolytic reaction and reaction and reactive sputtering. The following physical properties were investigated: amorphism, surface electron micrography, Si-N atomic distance, infrared adsorption spectrum, index of refraction, dielectric constant, electrical resistivity, ionic conductivity and polarization, breakdown voltage, MIS CV characteristics and silicon surface charge, and related phenomena.

Reactive Processing of Phase Objects, R. V. Pole, H. Wieder and R. A. Myers, *Applied Physics Letters* **8**, No. 9, 229-231 (May 1, 1966).

In conventional imaging of a phase object such as a thermoplastic recording, Eidophor, or phase hologram, the direct, or zero-order beam is discarded since information is carried only in the side orders. This means that a large fraction of the incident energy is lost, either by absorption or deflection out of the system and after a single pass through the phase object, makes no further contribution to the image. In the present Letter we show experimentally that this loss can be virtually eliminated by inserting the phase object inside a laser cavity.

Reactively Sputtered Silicon Dioxide Films, R. M. Valetta, J. A. Perri and J. Riseman, *Electrochemical Technology* **4**, No. 7-8, 402-406 (July-August, 1966).

The preparation and properties of reactively sputtered SiO_2 films have been studied as a function of variables such as rate of deposition, substrate temperature and oxygen pressure. The properties of the oxides, as determined by etch rate and IR spectra have been found to be strongly dependent on deposition rate. At deposition rates above $250\text{\AA}/\text{min}$, the deposited SiO_2 is extremely porous and contains large amounts of H_2O . Low substrate temperatures and high oxygen pressure also result in increased porosity of the films.

Recent Studies on the Optical Properties of Rare-Earth Metals, C. Chr. Schüller, *Proceedings of the International Colloquium on Optical Properties and Electronic Structure of Metals and Alloys*, September 1965, North-Holland Publishing Company, Amsterdam, p. 221 (1966).

Optical spectroscopy of the rare-earth metals has not received much attention in the past. This paper summarizes experimental results we have recently obtained and tries to compare them, together with some material available in the literature, to the theoretical information on the band-structure and the Fermi surface so far available. First, a short survey of the rare-earth metals is given, with special emphasis on their electronic structure and magnetic properties. Next, we present experimental data of the optical properties of several rare-earth metals at room temperature. There is a distinct difference between the trivalent, hexagonal elements, such as Gd and Lu, on the one hand, and the divalent, cubic metals Eu and Yb on the other. Dispersion curves of the latter show a striking agreement with those of Ba and Sr metal. Interpretation of the hexagonal group in terms of recently published band-structure calculations is attempted.

For Eu and Yb as well as Ba and Sr, no band calculations exist, but the similarity of their spectral behavior suggests that transitions involving the $4f$ band are absent at least in Eu. In addition to studies of the rare-earth metals in their paramagnetic state at room temperature, we have looked for the effect of magnetic order, occurring at lower temperature, on their optical properties. Anomalies in the dispersion, associated with either ferromagnetic or periodic spin-arrangements were found. The origin of these new effects is not clear at the present time. Some possibilities which have been suggested are compared to the experimental evidence. In a brief summary, we point out the importance of accounting for the strong anisotropy of the metals belonging to the hexagonal group by using single crystals for further optical studies.

Self Diffusion in Intrinsic Silicon, R. F. Peart, *Physica Status Solid* **15**, No. 2, K119-122 (1966).

The diffusion measurements reported by Valenta and Ramasastry, which show that self diffusion of Ge is greater in heavily n -type than in intrinsic Ge and less than the intrinsic value in heavily p -type Ge, strongly suggest that diffusion occurs by a vacancy mechanism in this semiconductor. To date no similar work on self diffusion in Si has appeared in the literature, although the diffusion of impurities in n - and p -type Si has been measured by Millea and by Williams.

Semi-Automatic Circuit Card and Module Testing, T. A. Moilan, *Electronic Industries* 25, No. 7, 92-95 (July, 1966).

A failure analysis laboratory involved with the analysis of circuit cards faces the need for some form of automation. A semi-automated circuit card and circuit module tester was developed to provide a test vehicle for failure analysis cases requiring detailed and flexible testing.

Silicon Nitride, a New Diffusion Mask, V. Y. Doo, *IEEE Transactions on Electron Devices* ED-13, No. 7, 561-563 (July, 1966).

Although in the last decade silicon dioxide has been used extensively as a diffusion mask in semiconductor device fabrication, it has many limitations. It fails to mask many important diffusants such as gallium, aluminum, zinc, and oxygen. The masking properties of silicon nitride have been investigated. The results are reported; these show that silicon nitride masks not only the same diffusants as silicon dioxide but also many diffusants where silicon dioxide fails.

Silicon Self-Diffusion, B. J. Masters and J. M. Fairfield, *Applied Physics Letters* 8, No. 11, 280-281 (June 1, 1966).

Measurements of silicon self-diffusion in high purity single crystal material, with ^{31}Si employed as a tracer of the atom migrations, are reported. Within the temperature range 1100°C to 1300°C, the self-diffusion coefficient is given by the expression $D = D_0 \exp(-\Delta H/RT)$, with values of $D_0 = 9000 \text{ cm}^2/\text{sec}$ and of $\Delta H = 118.5 \text{ Kcal/mole}$. These data, heretofore unreported in the literature, are of importance in the development of diffusion theory, as well as in the fabrication of silicon device structures.

Solution of Systems of Polynomial Equations by Elimination, J. Moses, *Communications of the ACM* 9, No. 8, 634-637 (August, 1966).

The elimination procedure as described by Williams has been coded in LISP and FORMAC and used in solving systems of polynomial equations. It is found that the method is very effective in the case of small systems, where it yields all solutions without the need for initial estimates. The method, by itself, appears inappropriate, however, in the solution of large systems of equations due to the explosive growth in the intermediate equations and the hazards which arise when the coefficients are truncated. A comparison is made with difficulties found in other problems in non-numerical mathematics such as symbolic integration and simplification.

Survey of Formula Manipulation, J. E. Sammet, *Communications of the ACM* 9, No. 8, 555-567 (August, 1966).

The field of formula manipulation is surveyed, with particular attention to the specific capabilities of differentiation, integration and the supporting capabilities of simplification, displays and input/output editing, and precision arithmetic. General systems—both batch and online—are described. Finally, some programs to solve specific applications are discussed.

Tarnish Films on Contact Materials, R. V. Chiarenzelli, *Proceedings of the 3rd International Research Symposium on Electric Contact Phenomena*, pp. 85-93 (June 6-10, 1966).

This paper will present some of the further results of the IBM Electrical Contacts Field Program, which was introduced in last year's conference. The degradation of contact materials with time at six field sites will be described as a function of atmospheric pollutants. The results of short-term laboratory exposures of some of these metals in tarnishing environments will be compared and contrasted with the field results. Methods which have been found in the field to significantly reduce the extent of tarnish formation on electric contact materials, or to reduce the effect of such tarnish products on contact behavior will be discussed.

Tin and Zinc Diffusion into Gallium Arsenide from Doped Silicon Dioxide Layers, W. von Münch, *Solid-State Electronics* 9, No. 6, 619-624 (June, 1966).

This paper describes the pyrolytic deposition of tin and zinc doped silicon dioxide layers on gallium arsenide. Doped layers of different thicknesses are used as solid sources for diffusion experiments at 1000°C. The conditions for "infinite" and "finite" sources are established. With multi-layer sources it is possible to obtain *npn* structures from a single diffusion operation.

Transformations of the Lunar Coordinates and Orbital Parameters, W. J. Eckert, M. J. Walker and D. Eckert, *Astronomical Journal* 71, No. 5, 314-332 (June, 1966).

Because of its high quality and long acceptance as the standard of comparison Brown's lunar theory will, for years to come, play a key role in the discussion of the observed lunar motion and in the critical examination of new, more precise theoretical developments. In the modification of Brown's basic solution to facilitate the comparison with observation the full precision of the solution was not preserved since this was not then considered necessary. Some of this loss of precision was regained by the Improved Lunar Ephemeris in 1952. The purpose of this paper is to make the full accuracy of Brown's solution available for the comparison with observation and to increase the precision of the relations between the computed coordinates and the parameters on which they are based. The precision of the solar terms in sin parallax is improved by more than an order of magnitude.

Letters

Gallium Arsenide Four-Layer Device, W. von Münch, *Solid-State Electronics* 9, No. 6, 667 (1966).

Note on Reflectance Measurements on Metals, W. E. Müller, *Applied Optics* 5, No. 5, 876 (May, 1966).